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UNITED STATES
DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
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INFORMATION CIRCULAR

MINING METHODS AND COSTS AT THE JUDGE MINE, PARK CITY, UTAH

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BY

GEO. S. KRUEGER AND E. A. HEWITT

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

MINING METHODS AND COSTS AT THE JUDGE MINE, PARK CITY, UTAH[1]

By Geo. S. Krueger[2] and E. A. Hewitt[3]

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7003."

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INTRODUCTION

This paper, describing mining methods and costs at the Judge mine, Park City, Utah, is one of a series being prepared by the Bureau of Mines on mining practices in the United States.

ACKNOWLEDGMENTS

The writers acknowledge the assistance of E. D. Gardner, supervising engineer, Southwest Experiment Station, Bureau of Mines; Paul H. Hunt, mine manager, Park Utah Consolidated Mines Co.; Wm. Osika, chief mine accountant; and Eric Neilson, assistant master mechanic of the mine.

LOCATION

The Judge mine in Park City district is about 1-1/2 miles south of Park City. The district lies on the eastern slope of the Wasatch Mountains, 30 miles southeast of Salt Lake City, and embraces a tract that lies between the crest of the main range on the west and the mountain meadows along the eastern-slope foothills. The altitude at the Union Pacific Railroad station at Park City is 7,000 feet above sea level. The town and mines are served by two railroads: one, 28 miles long, is a branch of the Union Pacific Railroad and connects with the main line at Echo, Utah, east of Ogden; the other, 35 miles long, is a branch of the Denver and Rio Grande Western Railroad and connects with the main line at Salt Lake City. The mines are also accessible by excellent automobile roads from Salt Lake City and surrounding points (fig. 1).

HISTORY

Systematic prospecting for ore in the region about Salt Lake began in 1862, when Colonel Connor, with his California volunteers, many of whom had participated in the '49 gold rush, established Camp Douglas at Salt Lake City. Ore was first found in the Park City district in 1869 and several small shipments were made, but the district did not become prominent until the discovery of the Ontario lode in 1872 by Rector Steen, a California miner who accompanied Connor's Volunteers. This discovery and others following it made the district one of the most important silver-lead-zinc mining camps in the country.

A remarkable feature of the Park City district is its longevity; active operations have been carried on for 64 years without complete cessation. While the depression of 1932-35 caused some curtailment, the years immediately prior to the depression saw the largest production in the history of the camp. The three largest producing companies in the district are now the Silver King Coalition Mines Co., the Park City Consolidated Mines Co., and the Park Utah Consolidated Mines Co. The last-

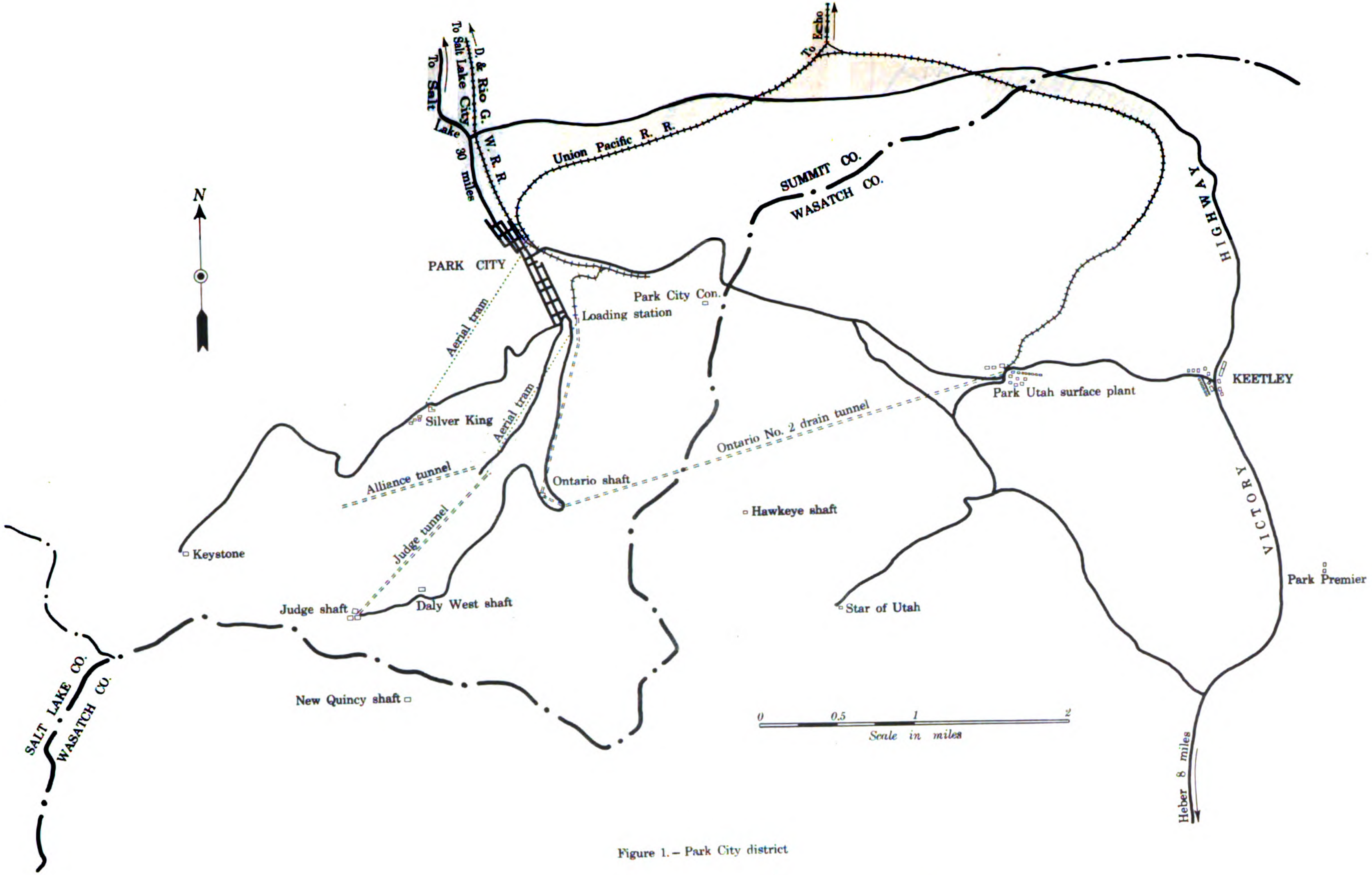

Figure 1.– Park City district

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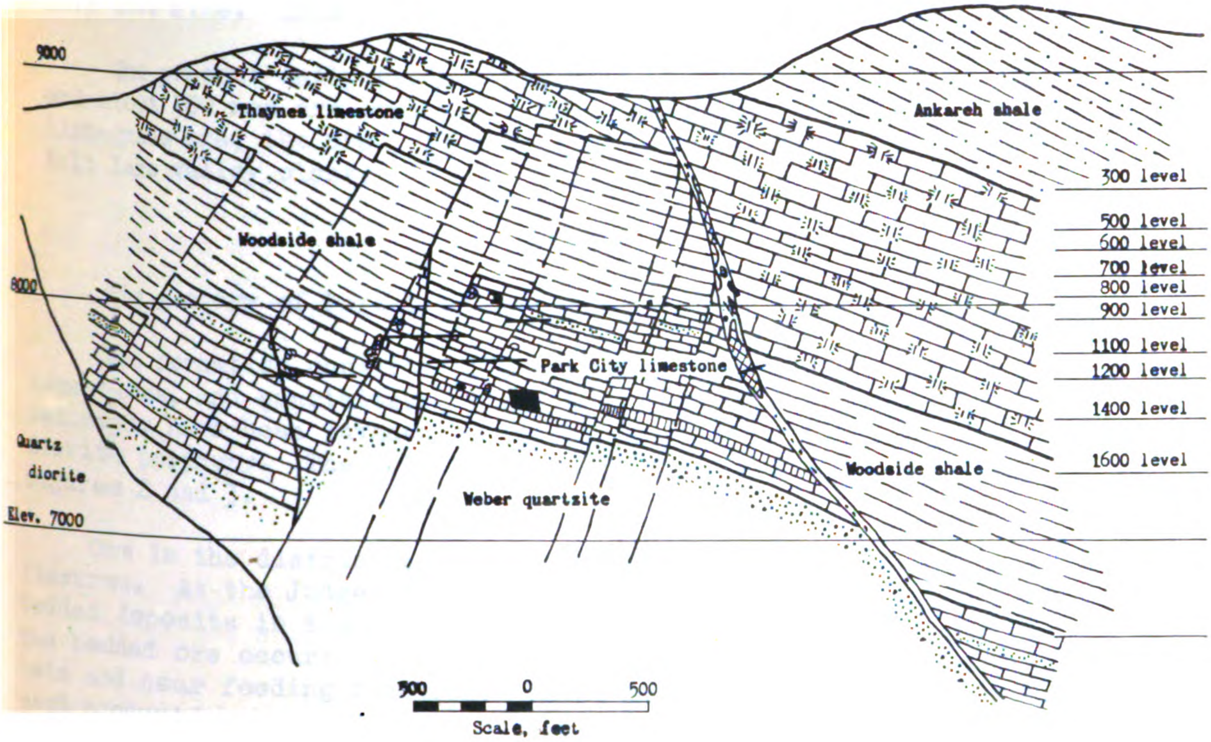

Figure 2.- Cross section through Judge mine, looking south 70° west.

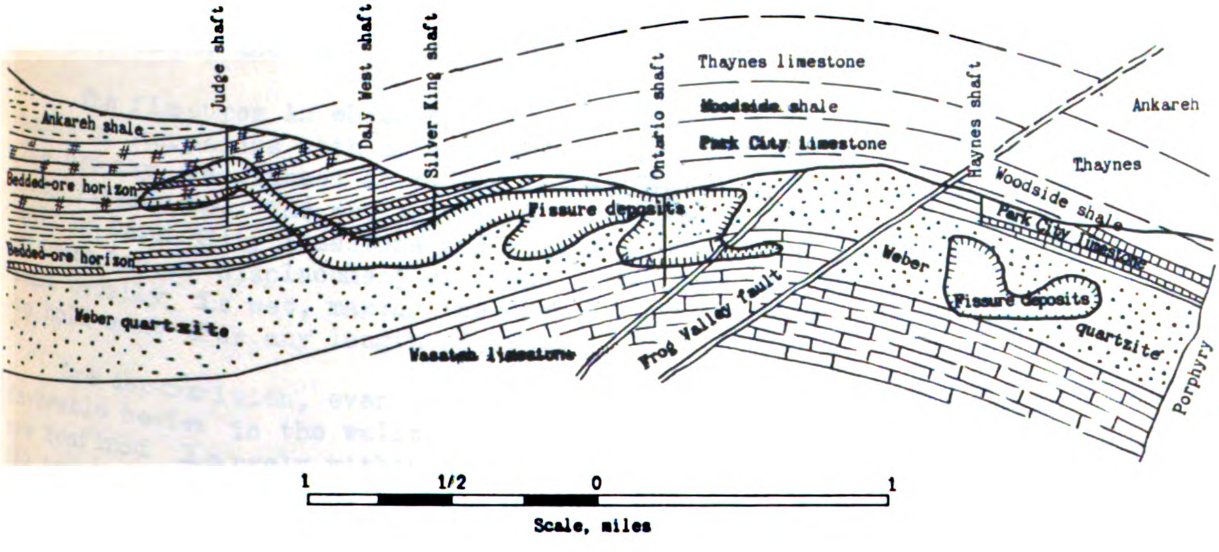

Figure 3.- Stratigraphic diagram across Park City anticline, looking north 15° west.

named company operates two units - the Park Utah unit, described by Hewitt[4], and the Park City unit, consisting of the Judge mine and the Daly West mine. This paper will be confined to the Judge mine.

The present daily production of the Judge mine is about 350 tons, and about 300 men are employed. With the exception of a small tonnage of high-grade ore, the ore produced is of milling grade and is treated at a Salt Lake valley plant.

GEOLOGY

The geology of Park City district has been described by Boutwell[5].

The formation consists of a series of sedimentary rocks - shales, limestones, and quartzites - which have been folded and faulted. The sediments have been invaded by intrusives, mainly diorite and quartz diorite porphyry. The relation between the different rocks is shown in figures 2 and 3.

Ore in the district occurs as bedded replacement deposits and in fissures. At the Judge mine about 60 percent of production has come from bedded deposits in the Park City limestone, which is about 600 feet thick. The bedded ore occurs in limestone members just above intercalated quartzite beds and near feeding fissures. Seven horizons have produced ore, but the most productive have been one at about 100 feet from the top of the Park City limestone and another at about 100 feet from the base of that limestone. The lower horizon is called the Jenney, named for Doctor Jenney, who examined the mine in 1902. The bedded deposits dip about 20° northerly and undulate in conformity with the bedding planes. They range in size from 2 to 20 feet or more in thickness, from a few feet to 100 feet or more in width, and have been found to extend as much as 6,000 feet in length.

The fissures in which the ore occurs show a series of nearly parallel bands of sulphides with alternating bands or lenses of altered limestone. The ore may be classed as medium hard. One or both walls are usually Park City limestone. The ore in the Daly fissure, however, usually has a footwall of Park City limestone and a hanging wall of Woodside shale; the fissure has a displacement of about 1,000 feet vertically. The hanging wall usually is wet, making the ground very heavy and almost impossible to hold open for any length of time.

Ore deposition, even in the fissures, is influenced greatly by favorable beds in the walls; for instance, ore shoots in the Daly fissure are confined largely within a range of 100 feet up and 100 feet down from the trace of the Jenney horizon on that fissure. Numerous internal gouge slips of irregular pattern affect mining operations in the fissure deposits.

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[4] Hewitt, E. A., Mining Methods and Costs at the Park Utah Mine, Park City, Utah: Inf. Circ. 6290, Bureau of Mines, 1930, 18 pp.

[5] Boutwell, John Mason, Geology and Ore Deposits of the Park City District, Utah: Geol. Survey Prof. Paper 77, 1912, 231 pp.

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As a general rule, the hanging wall is clearly demarcated but the footwall is poorly defined, as the ore tends to make off into the beds for short distances.

EXPLORATION

Exploration in the district has been entirely by the usual underground methods - tunnels, shafts, crosscuts, drifts, and raises. In the past, some exploration from underground positions has been done with diamond drills and long-hole hammer drills at various mines in the district, but as no ore discoveries resulted, prospect drilling has been abandoned. The ores of the district are usually too deep for churn drilling, although one company in recent years did some surface exploration in that manner.

A common method of attack in exploring for bedded deposits is to drive drifts and crosscuts beneath a favorable horizon. When stringers of ore are found in the fissures raises are driven to the favorable horizon. If ore is not found in a raise some drifting may be done at the favorable horizon.

Some geophysical prospecting has been tried at both the Park Utah mine and at the Judge mine, but indifferent results were obtained.

SAMPLING AND ESTIMATION OF ORE RESERVES

At the Judge mine, ore can usually be identified by inspection, but in new or in doubtful places cut samples are taken. Composite samples for each chute from a stope are made for each shift by taking a grab sample from each car.

Estimation of ore reserves at this mine is a difficult matter and no regular calculation is made. For special reports, an estimate is sometimes based largely upon experience at the mine rather than upon measurable dimensions and assays.

DEVELOPMENT

The Judge mine is served by two vertical shafts - the Daly West, 2,100 feet deep, and the Judge shaft, 1,600 feet deep. Ontario No. 2 Drain Tunnel, 22,500 feet long, connects with the Daly West shaft at the 2,100-foot level, and the Judge tunnel, 6,600 feet long, connects with the Daly West Shaft at the 750-foot level and with the Judge shaft at the 1,200-foot level. Figure 1 shows the location of these openings. The shafts are timbered with 10- by 10-inch timbers and have 2 hoisting compartments, 4-1/2 by 5 feet in the clear, and a 4- by 5-foot pipe and manway compartment. The tunnels are 6- by 9 feet in rock section timbered with 10- by 10-inch timber where necessary (fig. 4). Track is of 40-pound rails laid on 6- by 10-inch stringers, under which a water ditch is maintained.

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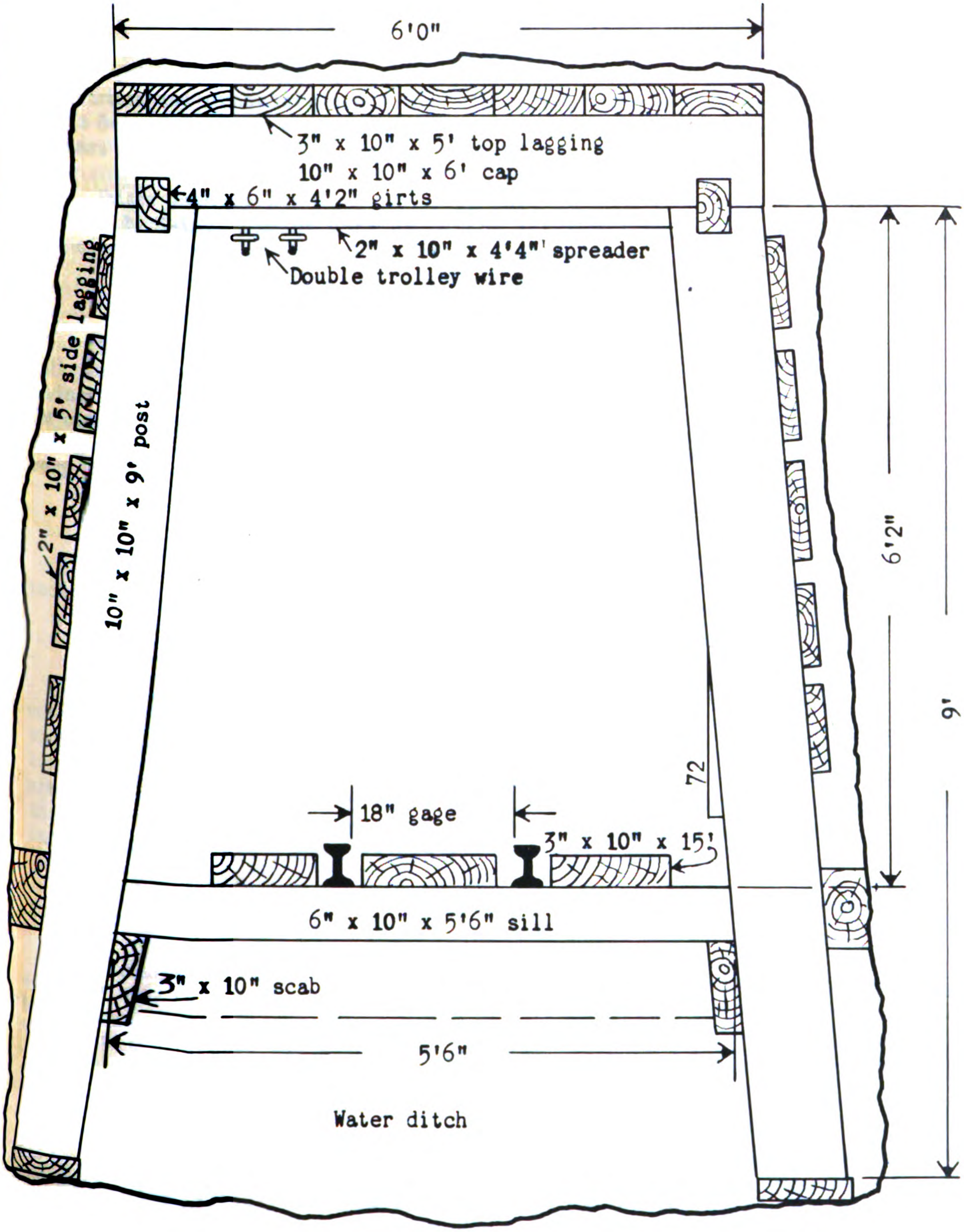

Figure 4.- Drain tunnel set.

At present main levels are maintained at the 700-, 900-, 1200-, 1400-, and 1600-foot levels with numerous sublevels of local extent. The drifts and crosscuts are 5 by 7 feet rock section and are timbered with 8- by 8-inch caps and about 8-inch round posts or 8- by 8-inch square posts.

Raises usually are about 5 by 11 feet in rock section and timbered with 8- by 8-inch timber sets at 5-foot intervals in both plan and section. Caps usually are set at right angles to the walls.

STOPING

Three methods of stoping are employed at the Judge mine: (1) Stull, (2) stringer set, and (3) top slicing. Stull stoping is little used, being adaptable only to small veins and thin beds. Stringer-set stoping is commonly applied to bedded shoots and fissure shoots where the walls are good. Top slicing has been adapted to local conditions wherever a very heavy hanging wall exists, as in the Daly fissure.

Stull Method

In the stull stopes ore is directed to the chutes by wings of 2-inch lagging. If accessible, they are filled with development waste.

Stringer-Set Method

Usually in the stringer-set stopes, mining is done by overhand methods. The back is supported by stringer sets comprising 8- by 8-inch timber caps supported by posts, usually 8-inch round timber obtained locally at low cost. When the stope is less than 10 feet wide, the caps are cut to fit; when greater than 10 feet, 10-foot caps are used joining the extension on a post. The back and floor are covered with 2-inch lagging. Chutes are placed at about 50-foot intervals.

Ore is shoveled into 1/2-ton stope cars or into wheelbarrows for transporting to the chutes.

In places in the bedded ore shoots where the bottom is undulating sills may be laid on ore and the downward extension removed by underhand mining. It is often necessary to use inclines to follow the undulations of the bottom, employing tugger hoists to pull cars up the slope.

Top Slicing

Top slicing is commonly applicable to fairly wide ore bodies too weak to stand without timber and having a weak capping or hanging wall which caves readily. Suitable timber should be available at a moderate cost to permit low mining costs. The method is thought to have been originated in the north of England and was introduced in this country

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about 55 years ago. It is widely applied in the iron mines of the Lake Superior districts, being standard underground practice on the Mesabi range, where the ore is soft, much of it being drilled with an auger. Little powder is required and timber is relatively cheap. No comparable conditions exist at the Judge mine, so no comparable costs can be obtained. Here the ore is hard and the deposits are deep. Timber is more expensive.

After years of experience with overhand timbered methods that sometimes resulted in disastrous caves and lost stopes, top slicing has become standard practice in heavy ground at the Judge mine. Although top slicing has been employed elsewhere in the mine, its principal application has been in mining fissure-ore having a shale hanging wall. The Daly fissure where the method is being currently used on the 1,600-foot level is a typical application. Figure 5 illustrates conditions in that part of the mine and shows details at the face of a slice, while figure 6 outlines the general scheme of development and rotation of slices. The slice is timbered with stringer sets, as in the stringer-set overhand method. The sets are spaced at the usual 5-foot intervals. The sills are of 8- by 8-inch timber and laid over the width of the ore. The posts are round timber about 8 inches in diameter and 6 feet long. They are spaced along the sills usually 5 feet apart, but may be spaced at different intervals to suit conditions. The sills become caps for the succeeding slice beneath; they are covered with 2-inch lagging to prevent intermixture of waste with the ore below. In many places on the Daly fissure, the Woodside shale on the hanging wall, especially if it contains water, will not remain in place until the ore is removed, and then it becomes necessary to stand sloping pressure posts faced with 2-inch lagging, and, sometimes angle stulls as well, to hold the hanging wall (fig. 5).

The face of the slice is advanced by a pilot heading broken with holes placed as in a drift round with the back holes omitted. Slabbing rounds to this heading complete breaking the face. Where waste inclusions are large or numerous a pilot heading, preferably along the hanging wall, may be driven to the end of the block to be mined. Then the remainder of the slice is completed by retreating, thus giving space in which to pile excessive hand-sorted waste. Drilling is done with Leyner machines mounted on columns, or sometimes with jackhammers manually supported.

Hoe-type scrapers operated by turbinair tuggers have been employed in the past to move the ore to the chute in top-slicing operations as well as in stringer-set operations; but as this arrangement does not lend itself readily to waste sorting, it has been discontinued. At present, ore is shoveled into 1/2-ton stope cars and trammed by hand to chutes over 18-inch-gauge, 12-pound track.

Little or no attention is necessary to facilitate caving of the completed slices. The hanging-wall pressure is in a direction diagonal to the sets and readily collapses the timber in most cases. To date, there has been no undue delay in caving, which might cause sudden block subsidence and air blasts endangering the working slice. As operations are at considerable depth, the subsidence does not reach the surface.

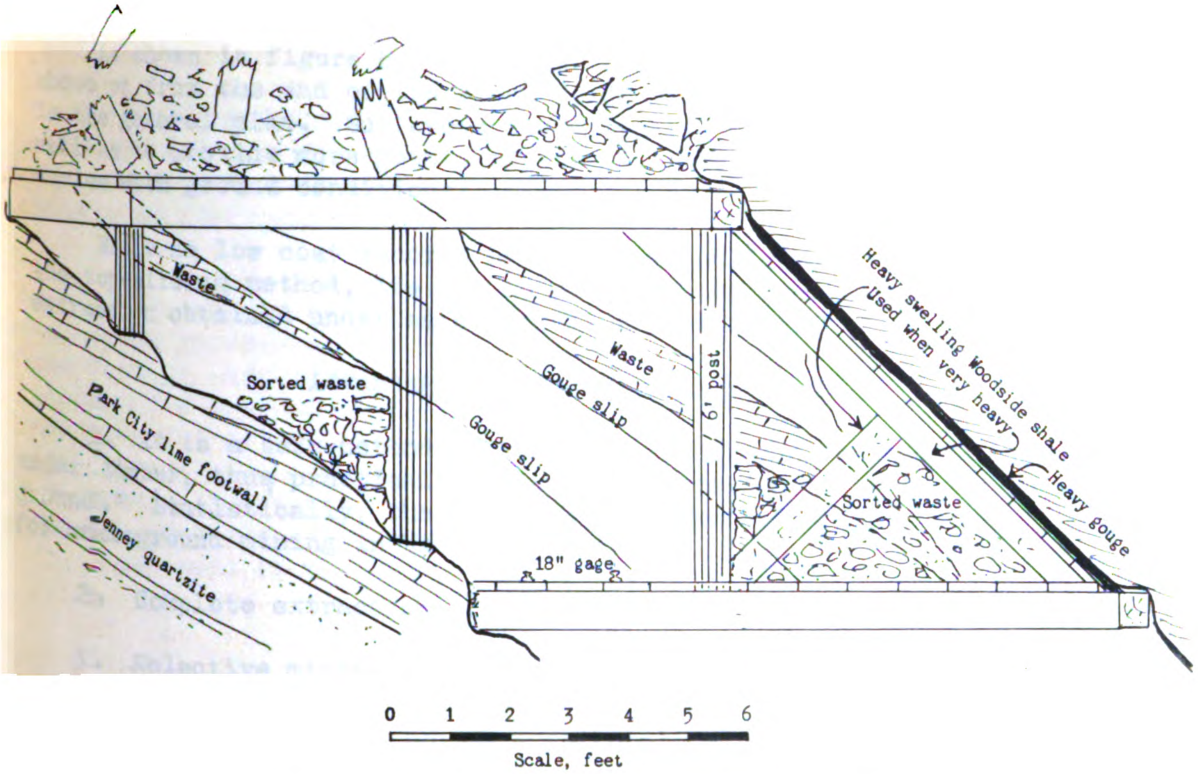

Figure 5.- Cross section of top-slice stope, looking at ore face.

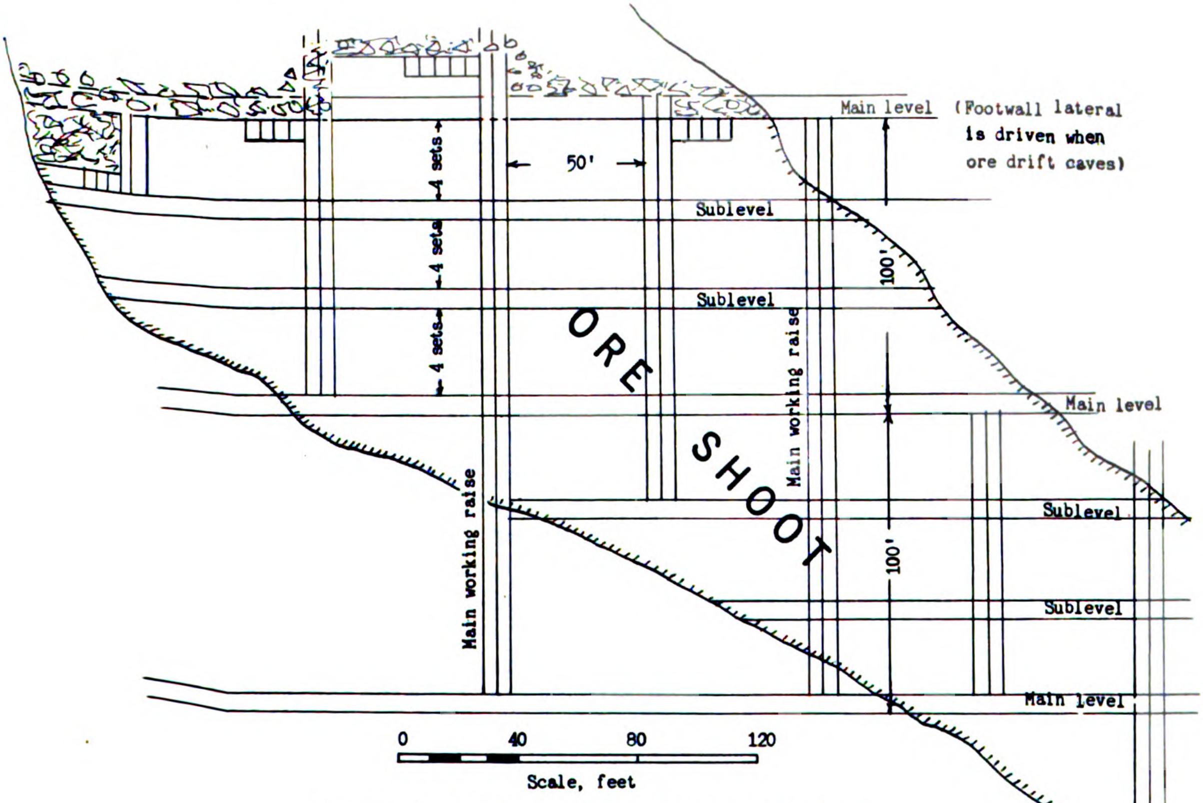

Figure 6.- Longitudinal section showing method of attack.

As shown in figure 6, an attack retreating from the limit of the ore shoot or from the end of the block being mined to the main working raise is the general plan. Sublevels are driven to outline the ore body as well as to provide more points of attack. The spacing of the sublevels varies with ground conditions.

While no low cost records have been established at this mine under the top-slicing method, its use is justified by the clean and complete extraction obtained under safe operating conditions.

Advantages of Top-Slicing Methods

1. It is a safe method of mining heavy ground, as workmen are always under timber, thus practically eliminating accidents due to "falling ground." Statistically, the system has the second lowest accident rate for underground mining in the United States.

2. Complete extraction of ore is possible.

3. Selective mining and waste sorting is facilitated.

4. In emergencies, such as when metal prices are low, the stopes may be shut down with little damage.

5. The system is not dependent upon a steady supply of waste filling, as is the case with overhand timbering methods when the hanging wall is heavy.

6. Top slicing permits the use of lower-grade timber and less labor in framing than does square-setting.

Disadvantages of Top-Slicing Method

1. All ore must be shoveled by hand; this would also be true of any system that permits hand sorting.

2. Ventilation may be difficult, for any caving system must destroy some openings. However, the ventilation problem has not hampered operations at the Judge mine.

3. The use of stoper drills is rarely possible as the slices are horizontal and call for flat holes. This is a debatable disadvantage, for, in the opinion of some operators, flat holes are desirable, even in overhand stopes, because such holes leave a less ragged back.

4. A large amount of development is necessary, but as all this is in ore the costs are affected little.

DRILLING PRACTICE

Three types of drilling machines are used - Leyner machines using 1-1/8-inch hollow round steel for drifting, crosscutting, and stoping; stoper drills using 1-inch hollow quarter octagon steel for raising and stoping; and jackhammers using 7/8-inch hollow hexagon steel for stoping, sinking, and plugging.

Conventional cross-bits, with a double taper of 14° and 5°, are used on Leyner steel, and a single taper on stoper and jackhammer steel. Crossbar mountings are used for drills in drifts and crosscuts, as these headings usually are driven under contract calling for both mucking and drilling simultaneously. The entire round, except the lifters, is drilled from a single setting of the cross-bar. The lifters are usually "kicked" in by sliding the machine on a lagging with the feet. A contract crew on each shift usually consists of three men - a miner and two muckers. The muckers assist the miner to set up and do any timbering that is necessary.

TRANSPORTATION

Ore is drawn from the stopes into 16-cubic-foot cars of the usual end-dump type. Trains comprising ten cars are hauled by horses to the shaft, where the cars are hoisted or lowered to the 1,200-foot level on double-deck cages operating in balance. Here trains of 30 cars are made up and hauled to bins at the portal of the Judge tunnel, 6,600 feet distant, by 4-ton, 250-volt, direct-current locomotives. From these bins the ore is transported by aerial tram about a mile to railroad cars.

The Judge shaft is equipped with a 250-horsepower, second-motion, alternating-current, electric hoist placed at the collar of the shaft. A rather unusual, if not unique, signal system is employed at this shaft. The usual electric-bell system is installed, but the signals can only be given from the cage, not from station contacts. The installation consists of a copper trolley wire extending the depth of the shaft in each compartment. By a lever arrangement on the cage, contact is made with this trolley wire, which completes the circuit through the hoisting cable to the hoist. This system makes it unnecessary to have an auxiliary pull-cord system to control the cage between levels, as in shaft inspection. It also makes for safety, as there are no station contacts to be rung by mistake.

Supplies are handled through raises equipped with a V-slide, on which a supply boat (fig. 7) is operated by a turbinair hoist. A special feature of this boat is the rollers, which minimize the friction and protect both the slide and the boat from excessive wear.

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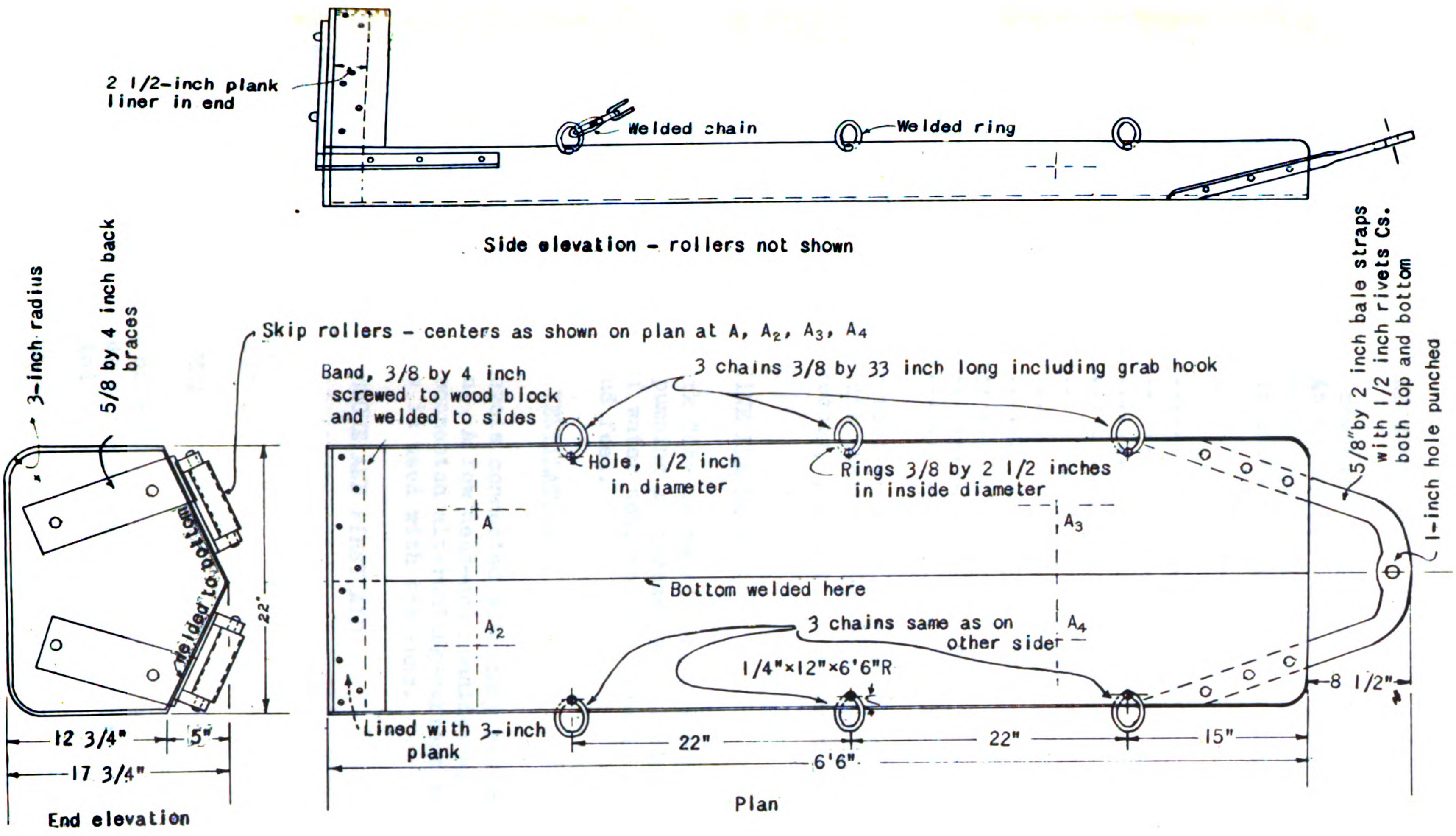
2 1/2-inch plank liner in end
Welded chain
Welded ring
Side elevation - rollers not shown
3-inch radius
5/8 by 4 inch back braces
Skip rollers - centers as shown on plan at A, A_2, A_3, A_4
Band, 3/8 by 4 inch screwed to wood block and welded to sides
3 chains 3/8 by 33 inch long including grab hook
5/8" by 2 inch bale straps with 1/2 inch rivets Cs. both top and bottom
1-inch hole punched
Hole, 1/2 inch in diameter
Rings 3/8 by 2 1/2 inches in inside diameter
A
A_2
A_3
A_4
Welded to bottom
22"
Bottom welded here
3 chains same as on other side
1/4"×12"×6'6"R
8 1/2"
12 3/4"
5"
17 3/4"
End elevation
Lined with 3-inch plank
22"
22"
15"
6'6"
Plan

Weight complete - 310 pounds

Figure 7.- Boat for hoisting supplies into stopes.

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WAGE AND CONTRACT SYSTEM

The labor for the mine is composed largely of men who live in Park City and nearby communities. About 75 percent are native Americans and the rest are naturalized citizens. The following is the current (August 1937) wage scale, which is adjusted to the Butte scale of wages based upon the price of copper.

Cage tender	$ 6.25
Hoistman	6.75
Miners	5.75
Motormen	5.75
Muckers	5.25
Nippers	5.50
Pipemen	5.75
Shaftmen	6.75
Timbermen	5.75
Trackmen	5.75

Current contract rates per foot are: Raises, 2-compartment, $6.25 for the first 50 feet, thence an additional 50 cents for each additional 50 feet in height; drifts and crosscuts, $4.25, with an additional $1.10 per foot for timbered sections.

MINE DRAINAGE

As mining districts go, Park City is considered a wet district, but with long drain tunnels little pumping is necessary now. The Judge tunnel carries about one second-foot of water now, and the Ontario no. 2 drain tunnel discharges about 14 second feet.

VENTILATION

The shafts, tunnels, and levels connected with many raises usually afford ample natural ventilation. A few dead-end headings are ventilated by small fans driven by direct-connected alternating-current motors. Twelve-inch galvanized-iron pipe is used with the fans.

MINE RESCUE AND FIRST AID

All shift bosses and many other employees are trained in first aid and in mine rescue. Breathing apparatus at the mine is kept in good order, and the usual stretchers and first-aid materials are at convenient places.

SUMMARY OF COSTS

Table 1 gives unit costs of mining at the Judge mine for the first half of 1937, and table 2 gives a summary of costs in units of labor, power, and supplies for the same period.

TABLE 1. - Costs of mining at the Judge mine for the first 6 months of 1937

Tons hoisted: 39,250.

Mining method: Top slicing (2/3 of tonnage)
and stringer set (1/3) costs not segregated

	Labor	Compressed-air drills, steel	Power	Explosives	Timber	Other supplies	To
Development....	$0.834	$0.114	$0.069	$0.134	$0.182	$0.005	1.
Mining.........	2.589	.228	.138	.236	.990	.018	4.
Transportation underground..	.433	-	.066	-	-	.052	.
General underground..	.788	-	-	-	-	.302	1.
Surface1/......	.495	-	.015	-	-	.142	.
Total.....	5.139	.342	.288	.370	1.172	.519	7.

1/ Chargeable to underground.

TABLE 2. - Summary of costs in units of labor, power, and supplies at the Judge mine for the first 6 months of 1937

	Development	Stoping	Tota
Labor (man-hours per ton):			
Breaking (drilling and blasting)..........	0.30	0.87	1.1
Timbering................................	.14	.42	.5
Mucking..................................	.25	1.46	1.7
Haulage and hoisting.....................	.29	.83	1.1
Supervision..............................	.03	.06	.0
General..................................	.26	.53	.7
Average tons per man per shift underground.....			1.1
Hours per ton, total labor underground.........			5.4
Average tons per man-shift on surface..........			9.5
Labor, percentage of total cost................			65.7
Power and supplies:			
Explosives (pounds per ton, 35-percent dynamite)............................			3.3
Timber, board feet per ton.................			50.5
Total power (kw.-hrs. per ton):			14.5
Air compression........................	10.3		
Hoisting and haulage...................	3.3		
Ventilation............................	.2		
Lighting...............................	.7		
Other supplies, in percentage of total power and supplies....................			19.3
Supplies and power, percentage of total cost.............................			34.3

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